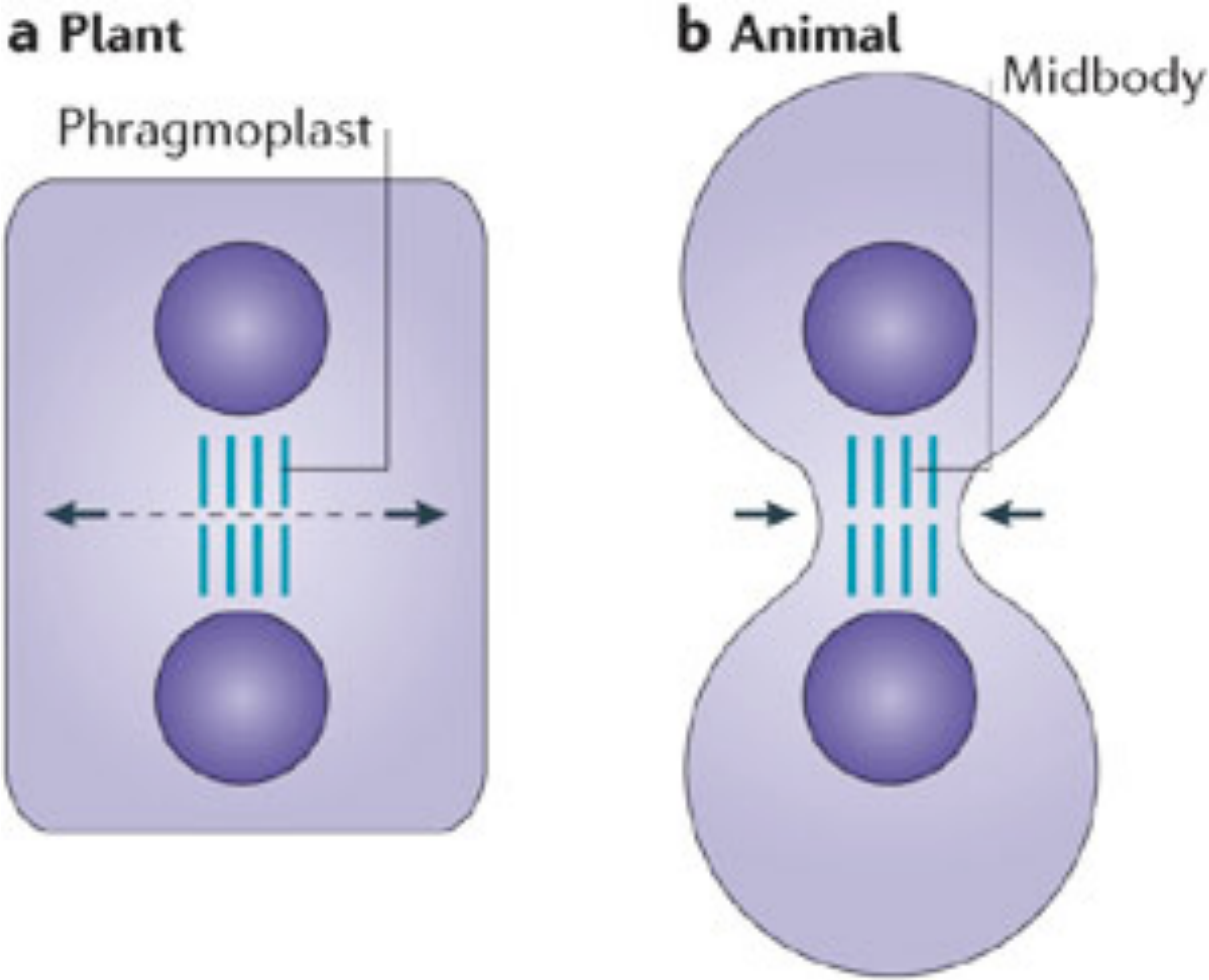
Synthetic Biology and reshaping plant form

Jim Haseloff

Department of Plant Sciences, University of Cambridge

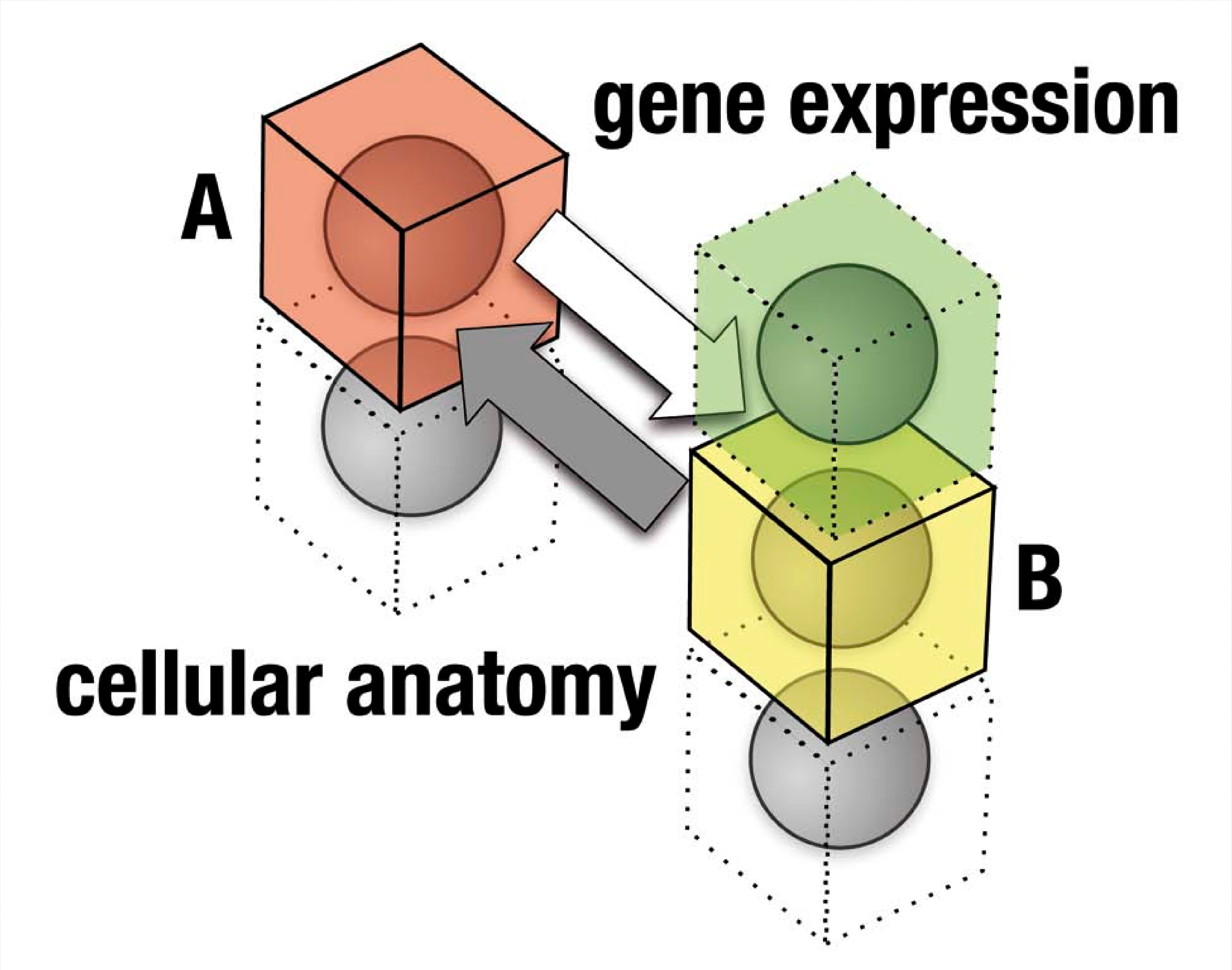
http://www.plantsci.cam.ac.uk/Haseloff/

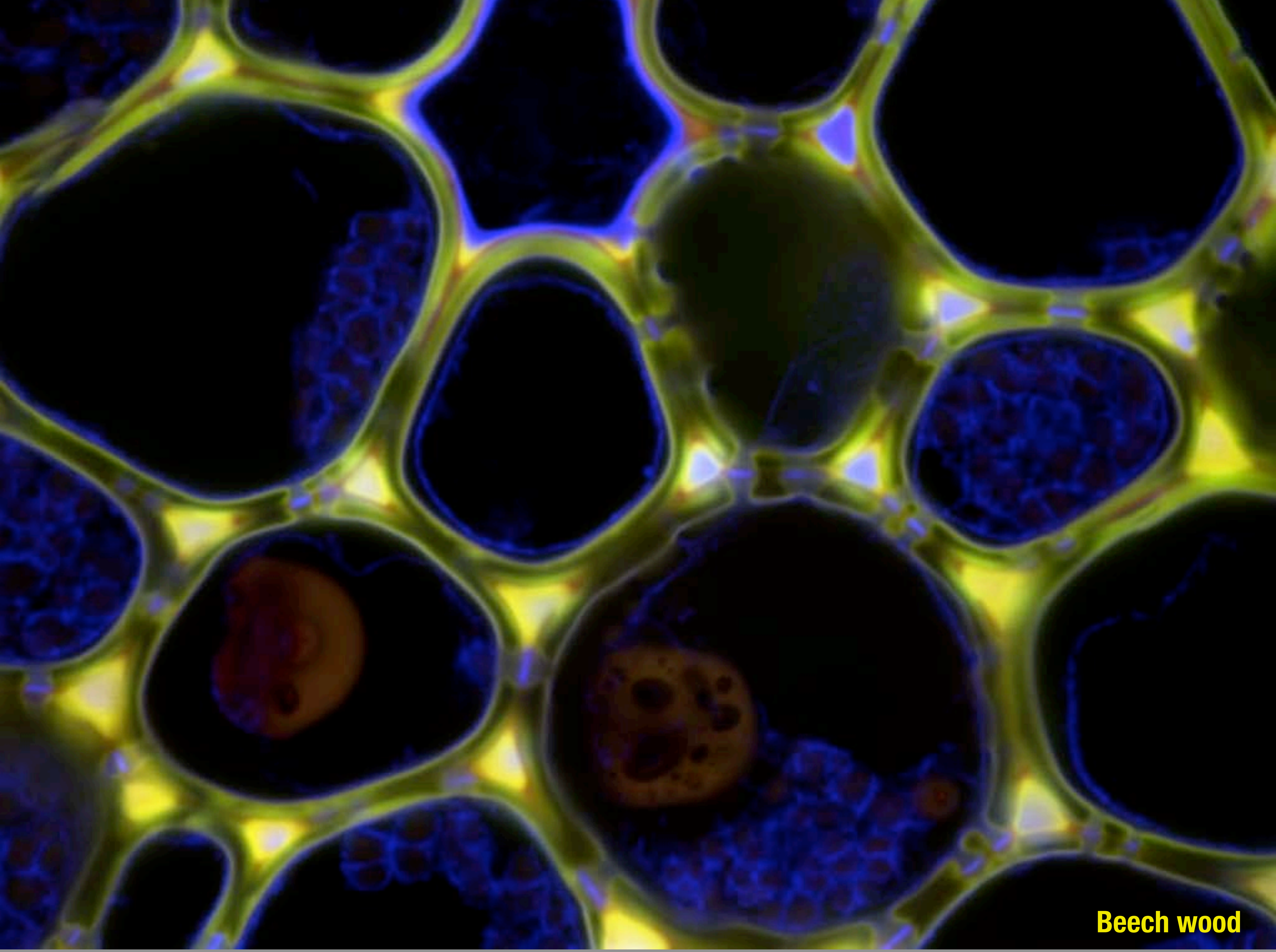


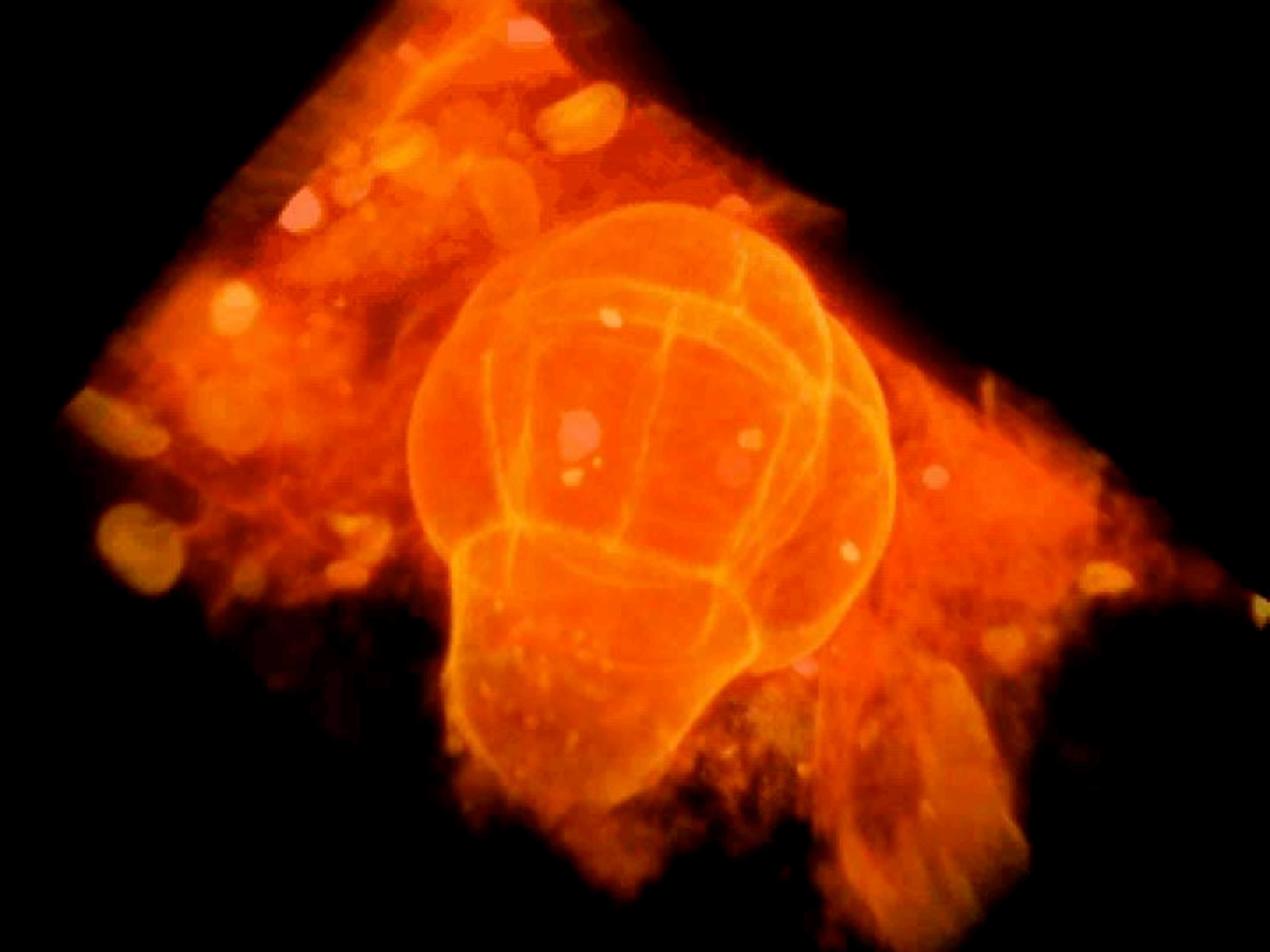
immobile cells

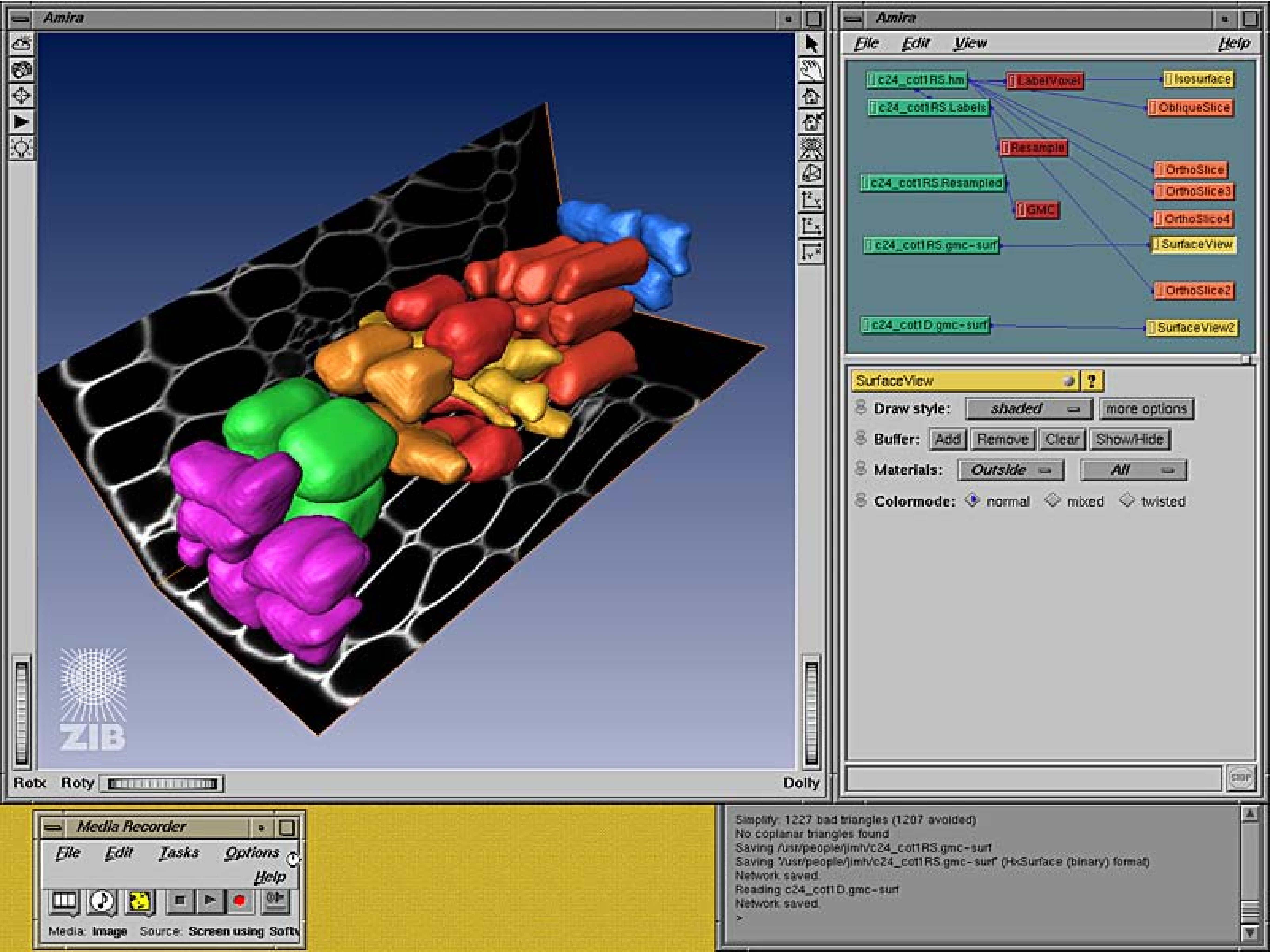
cell migration and apoptosis

Self-organisation and morphogenesis result from feedback between genetic and physical systems

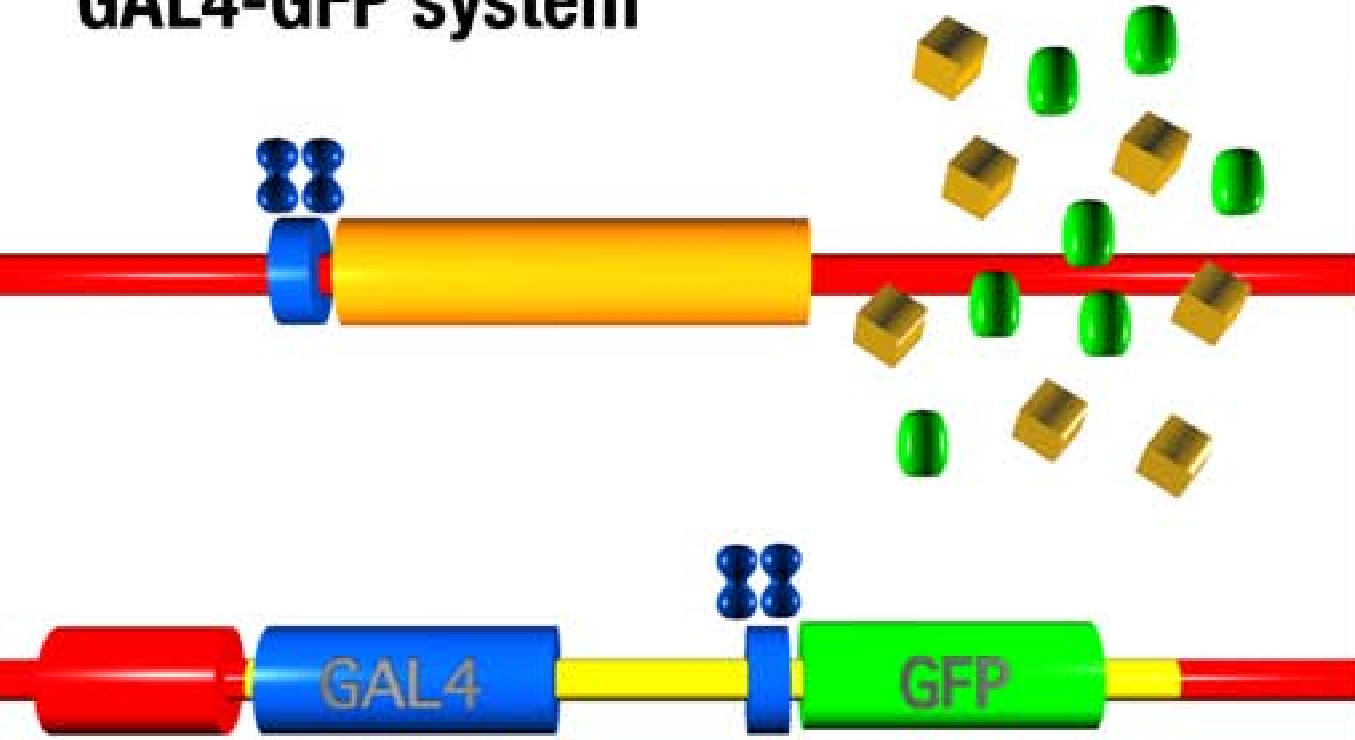



Beech wood

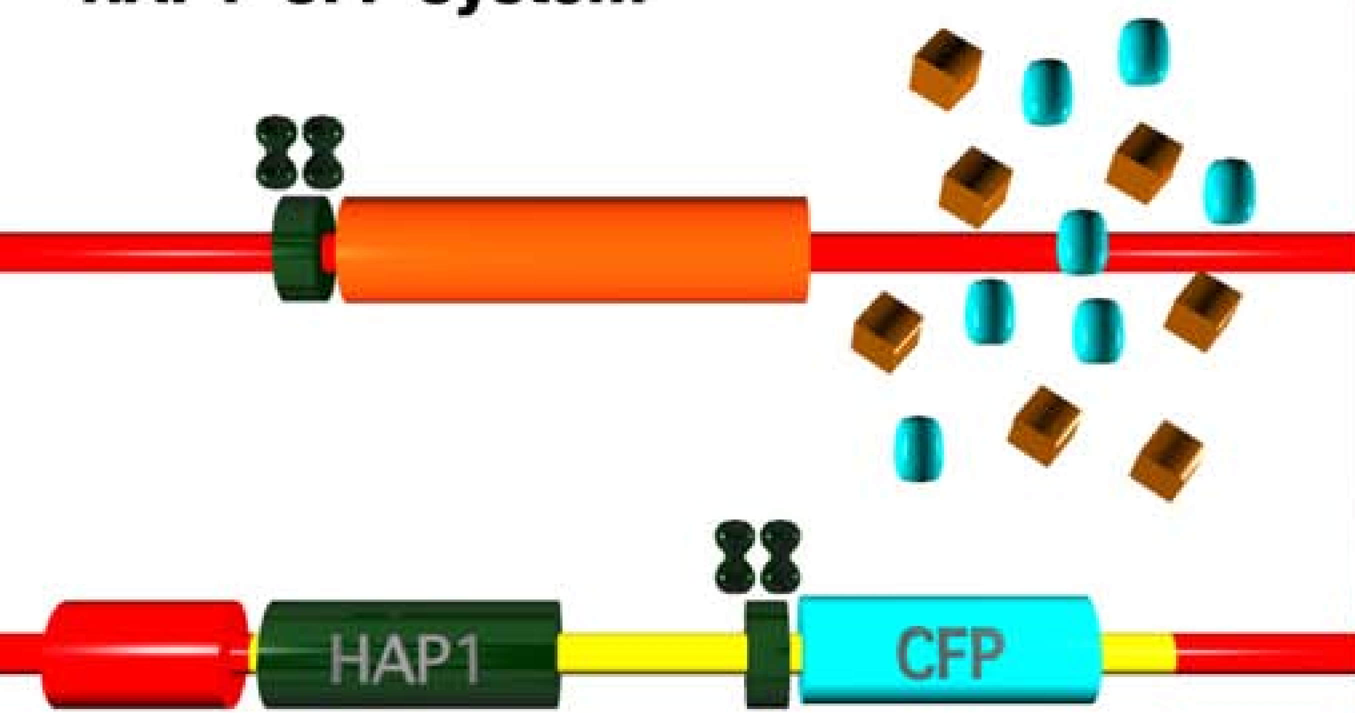


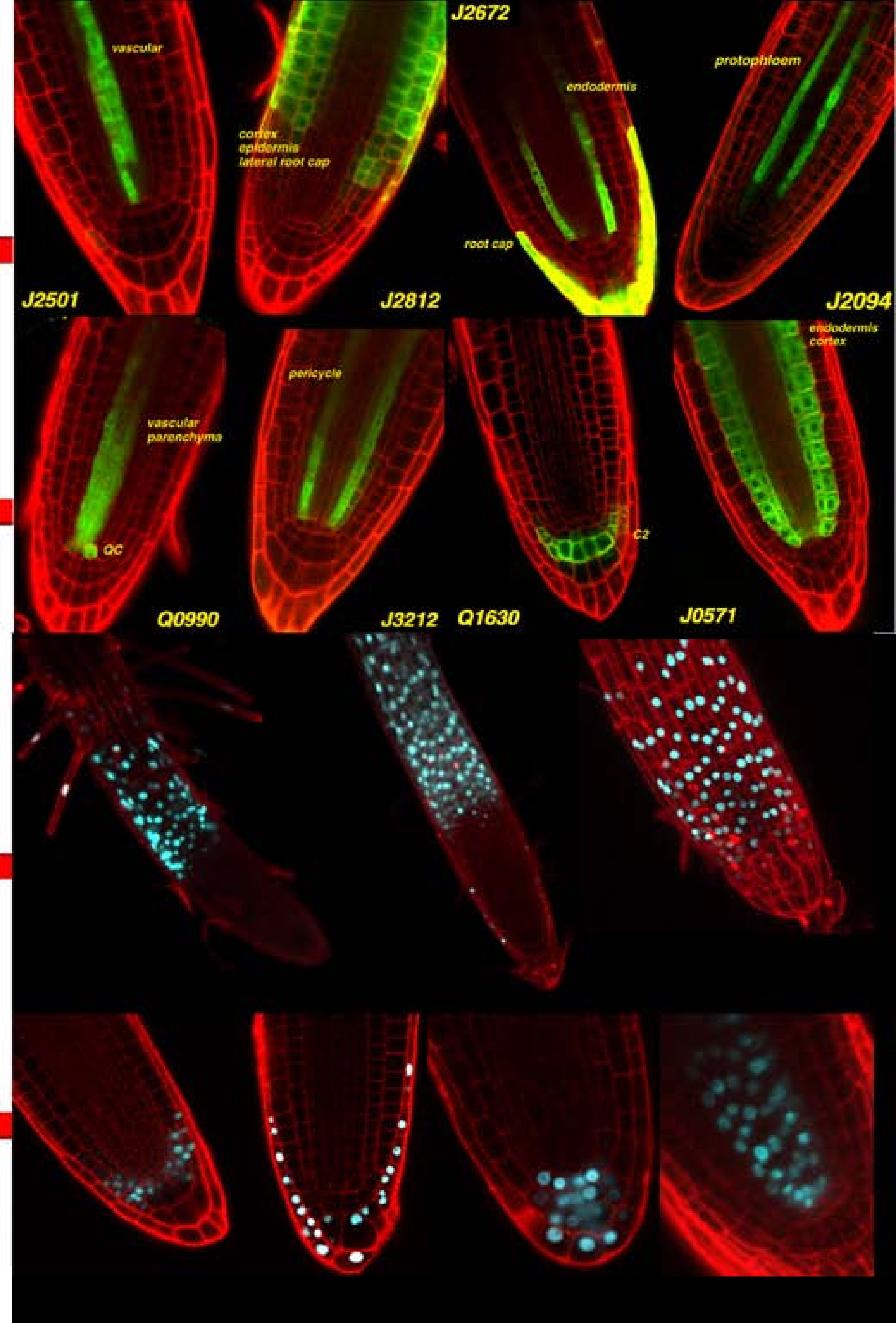

Amira
Amira
File Edit View Help
c24_cot1RS.hm
c24_cot1RS.Labels
LabelVoxel
Isosurface
ObliqueSlice
Resample
OrthoSlice
OrthoSlice3
OrthoSlice4
c24_cot1RS.Resampled
GMC
c24_cot1RS.gmc-surf
SurfaceView
OrthoSlice2
c24_cot1D.gmc-surf
SurfaceView2
SurfaceView
Draw style: shaded more options
Buffer: Add Remove Clear Show/Hide
Materials: Outside All
Colormode: normal mixed twisted
ZIB
Rotx Roty Dolly
Media Recorder
File Edit Tasks Options Help
Media: Image Source: Screen using Soft
Simplify: 1227 bad triangles (1207 avoided)
No coplanar triangles found
Saving /usr/people/jimh/c24_cot1RS.gmc-surf
Saving '/usr/people/jimh/c24_cot1RS.gmc-surf' (HxSurface (binary) format)
Network saved.
Reading c24_cot1D.gmc-surf
Network saved.

GAL4-GFP system



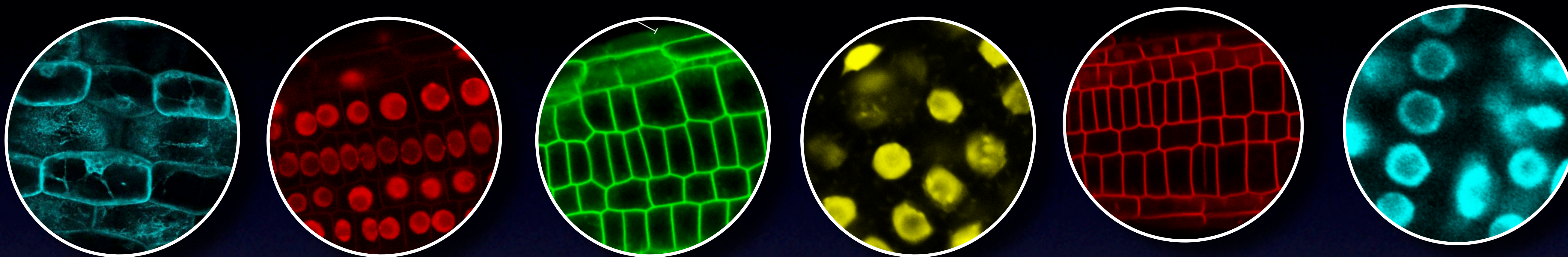
HAP1-CFP system

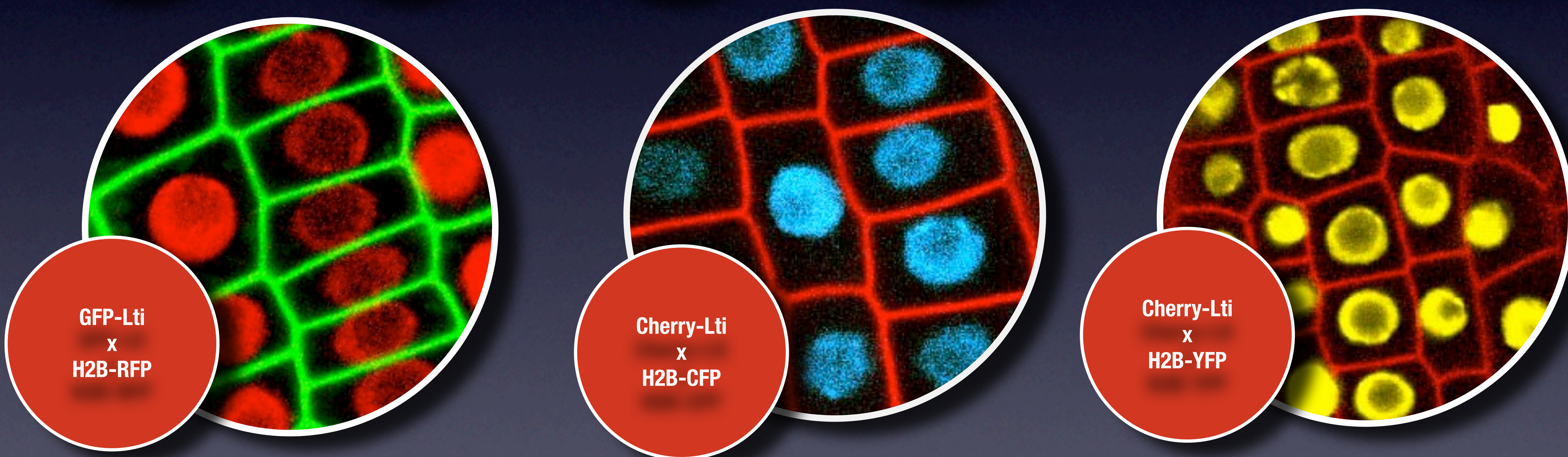




Triggers for gene expression

Live imaging of gene expression

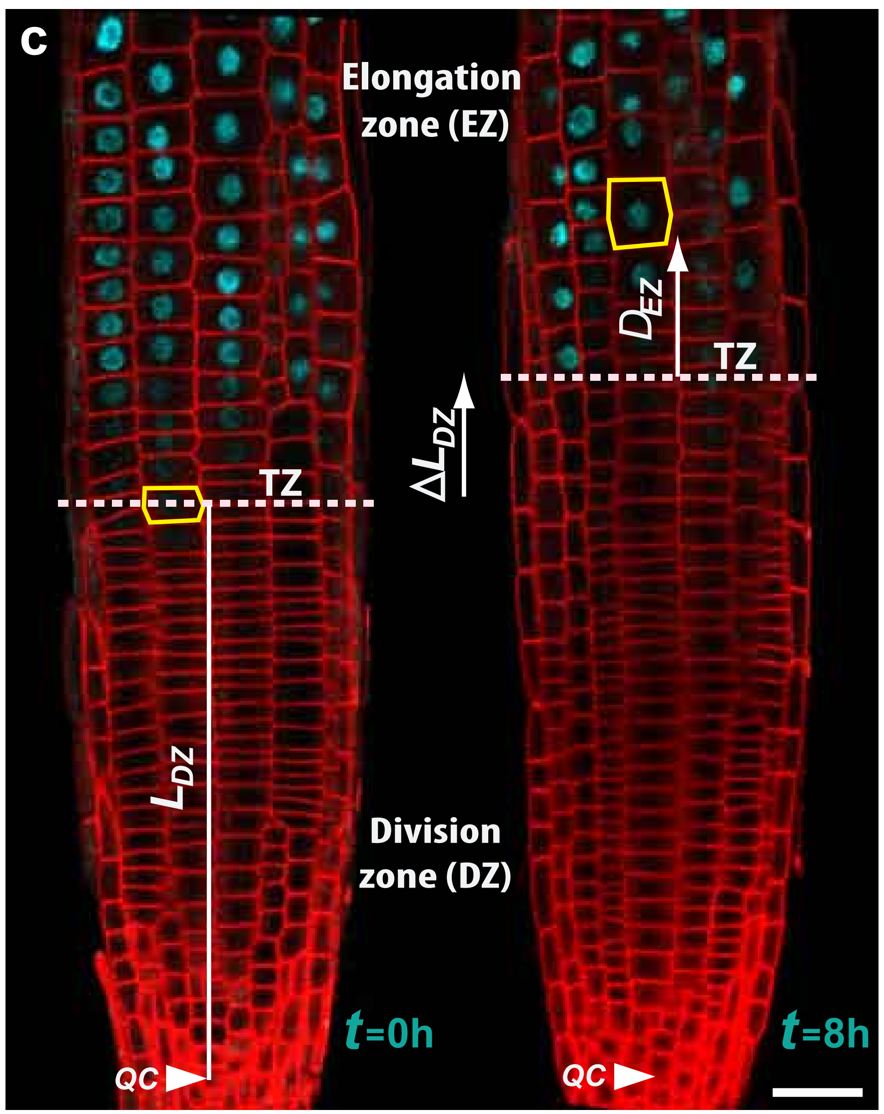


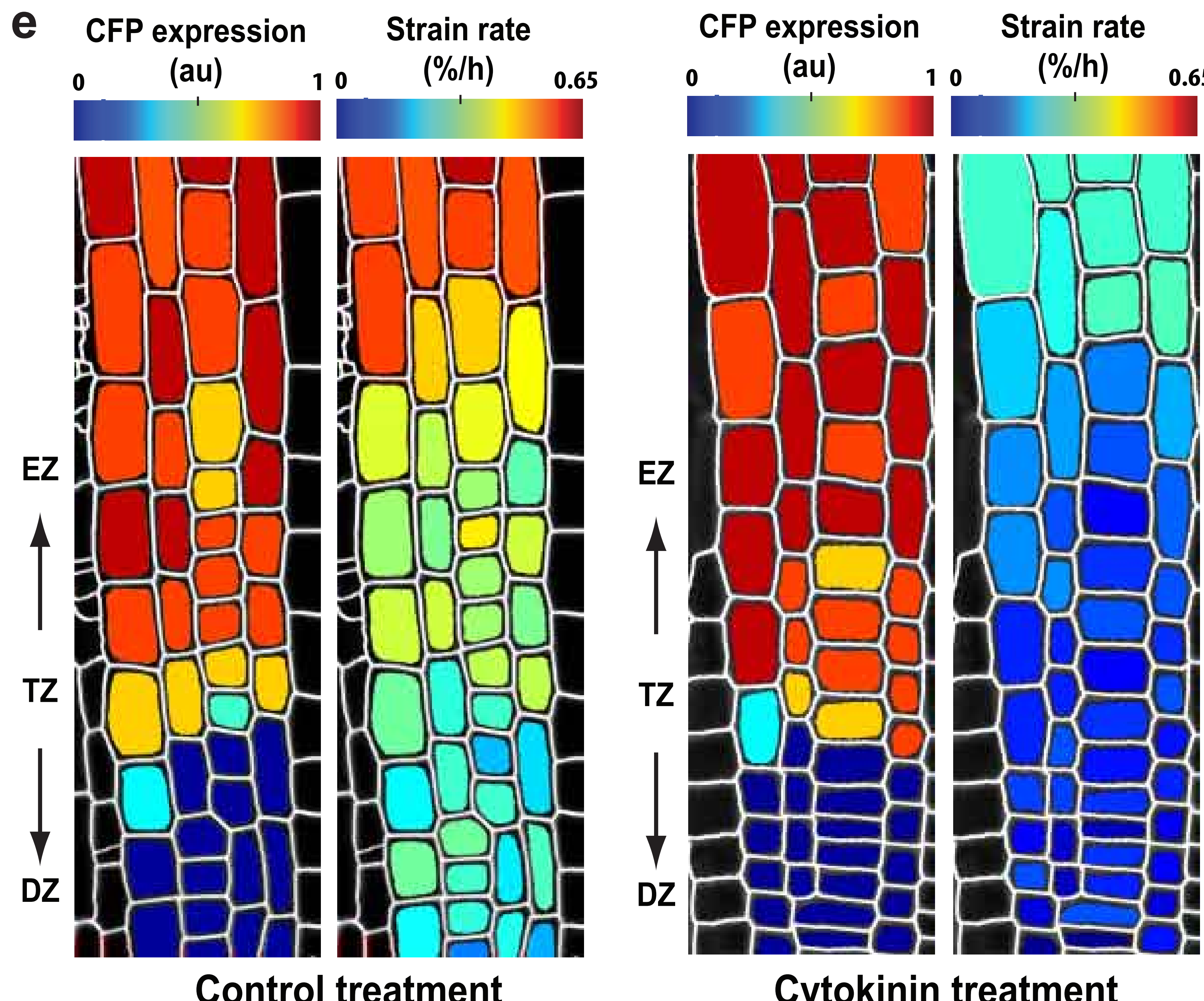


Fernan Federici

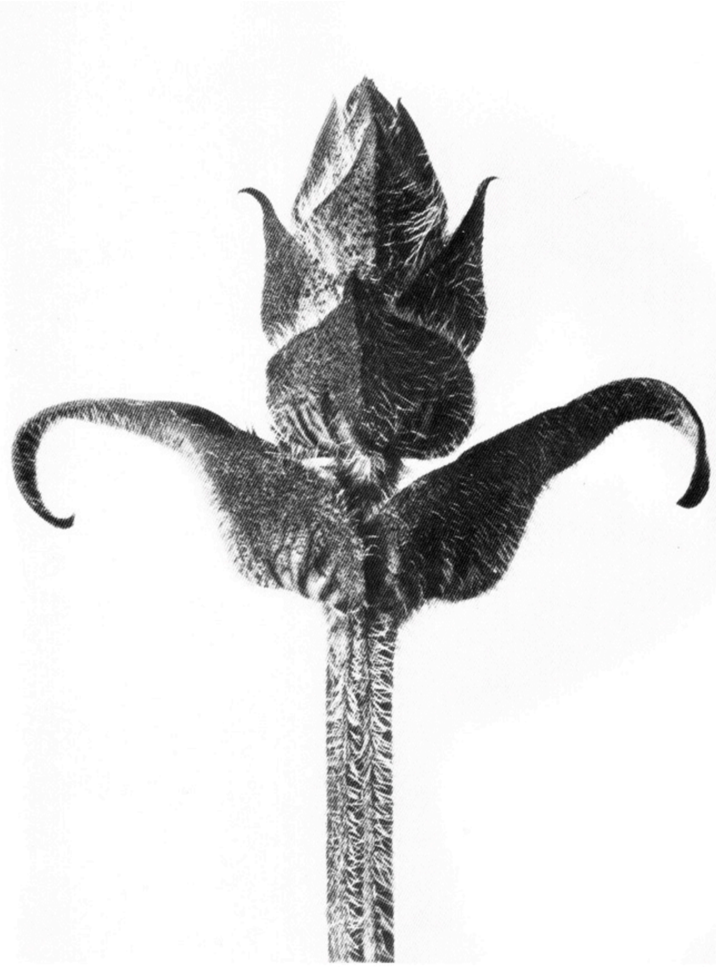
In planta cytometry

Provides a quantitative view of plant microarchitecture and dynamics of cell shape and gene expression





Lionel Dupuy & Fernan Federici



87. *Prunella grandiflora*. Large-flowered Selfheal. Young shoot enlarged 7.2 times.

95. *Aquilegia chrysantha*. Golden-flowered Columbine. Flower enlarged 5.4 times.

75. *Taraxacum officinale*. Common Dandelion, Blowballs. Flower bud enlarged 7.2 times.

112. *Centaurea macrocephala*. Great-headed Centaury or Knapweed. Seed head enlarged 4.5 times.

103. *Abutilon*. Lime Mallow. Seminal capsules enlarged 5.4 times.

Blossfeldt, 1928

94. *Allium Ostrowskianum*. Garlic. Umbel enlarged 5.4 times.

Empirical rules describe cell division

1. Hofmeister's rule (1863)
Cell plate formation normal to the growth axis.

2. Sachs' rule (1878)
Cell plate formation at right angles to existing walls.

3. Errera's rule (1888)
Cell plate of minimal area for cutting the volume of the cell in half.

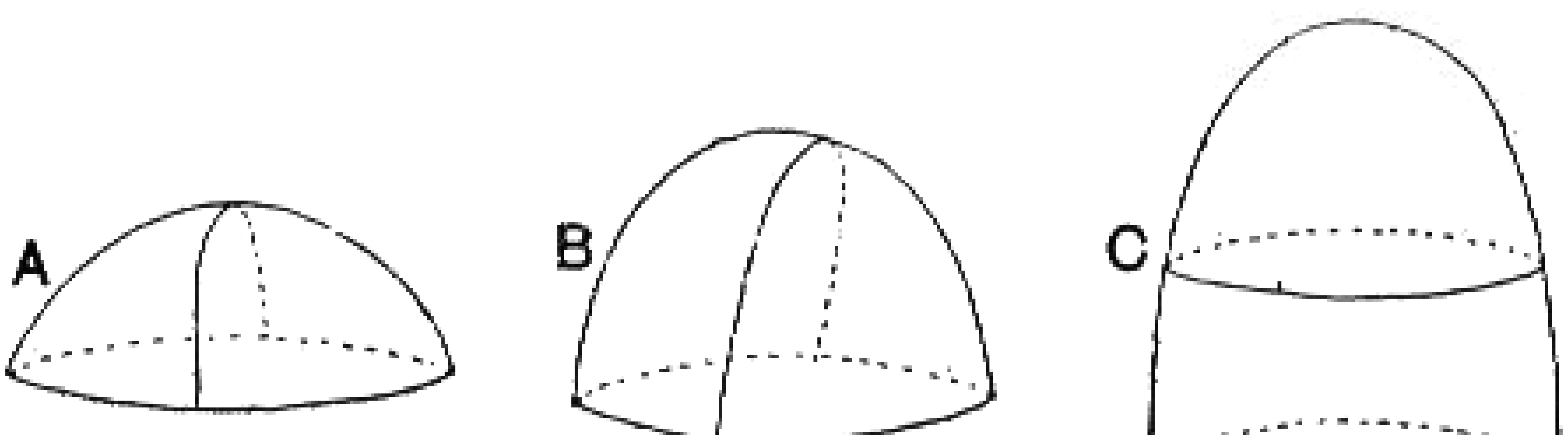
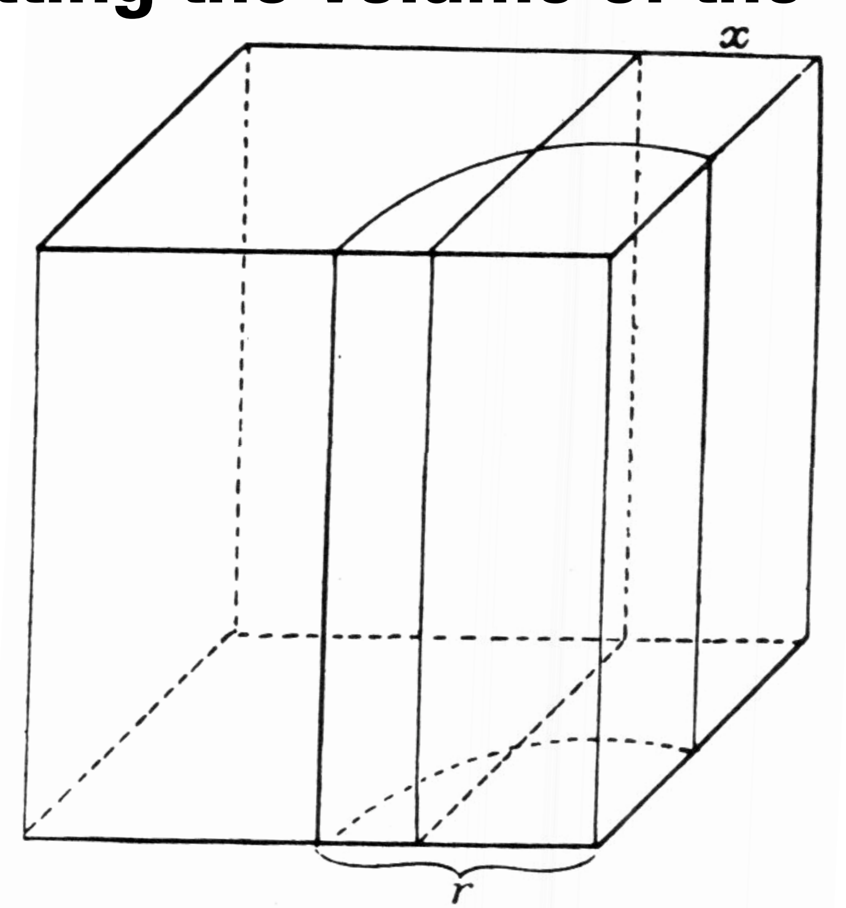
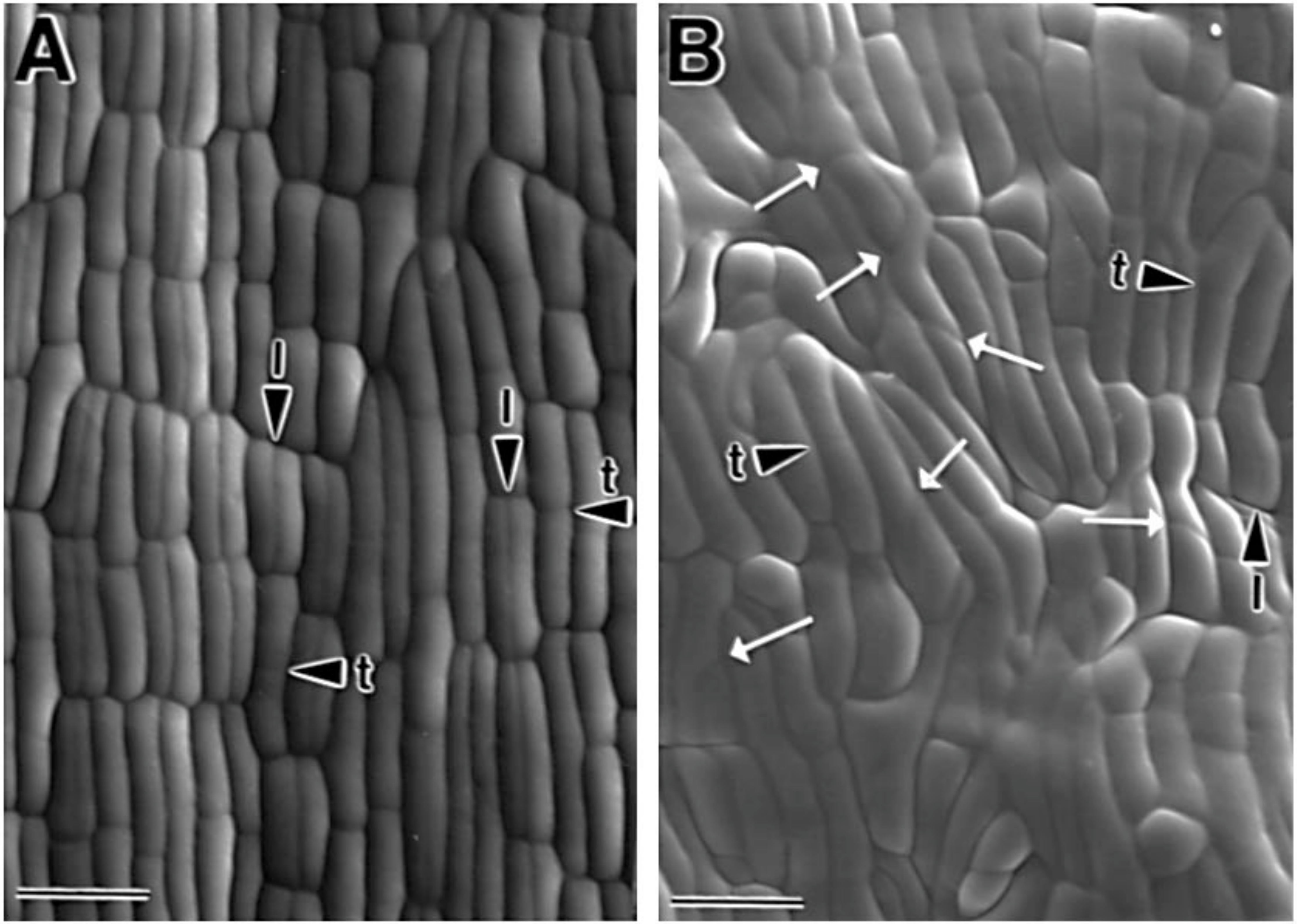


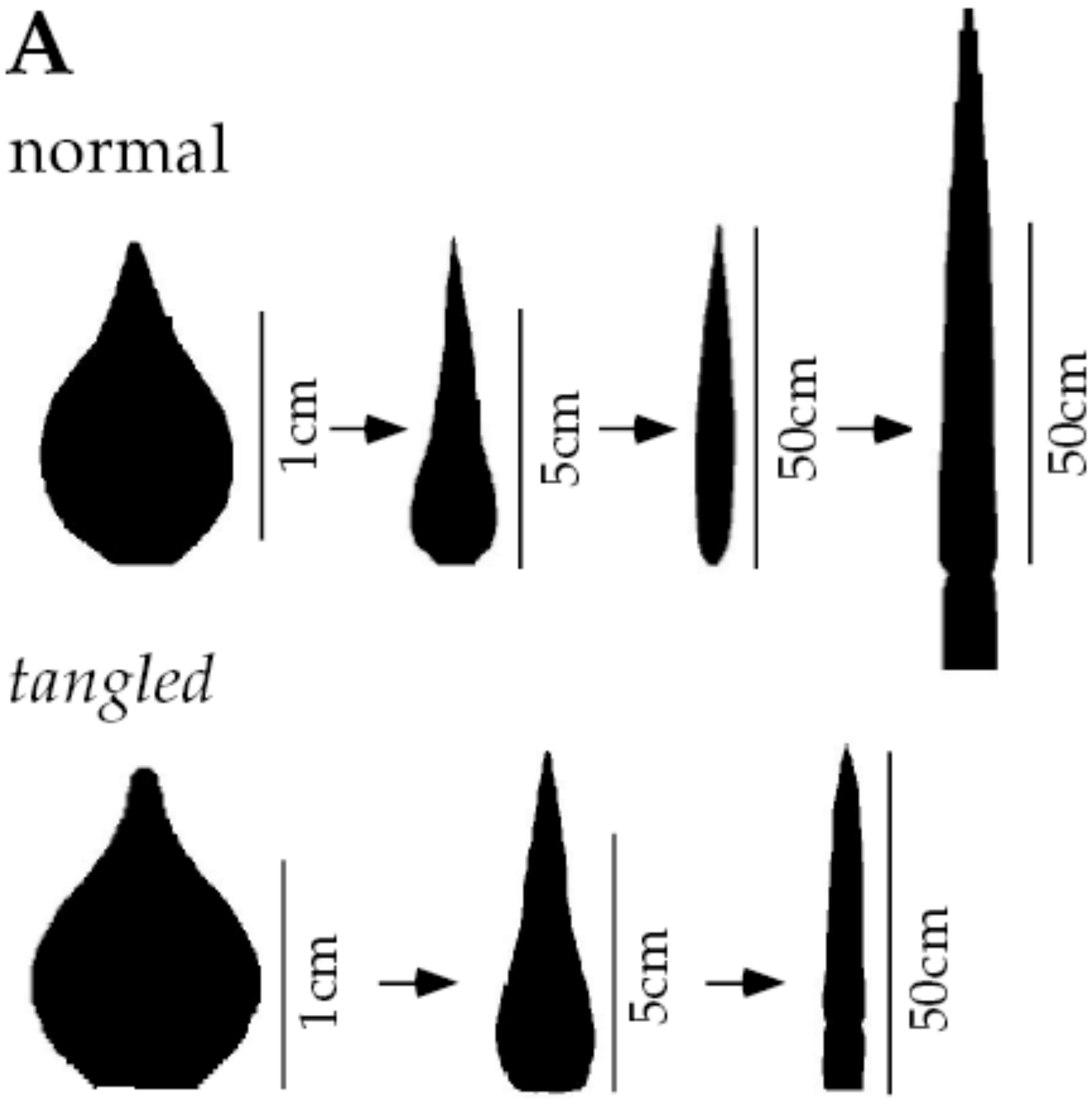
Fig. 225.

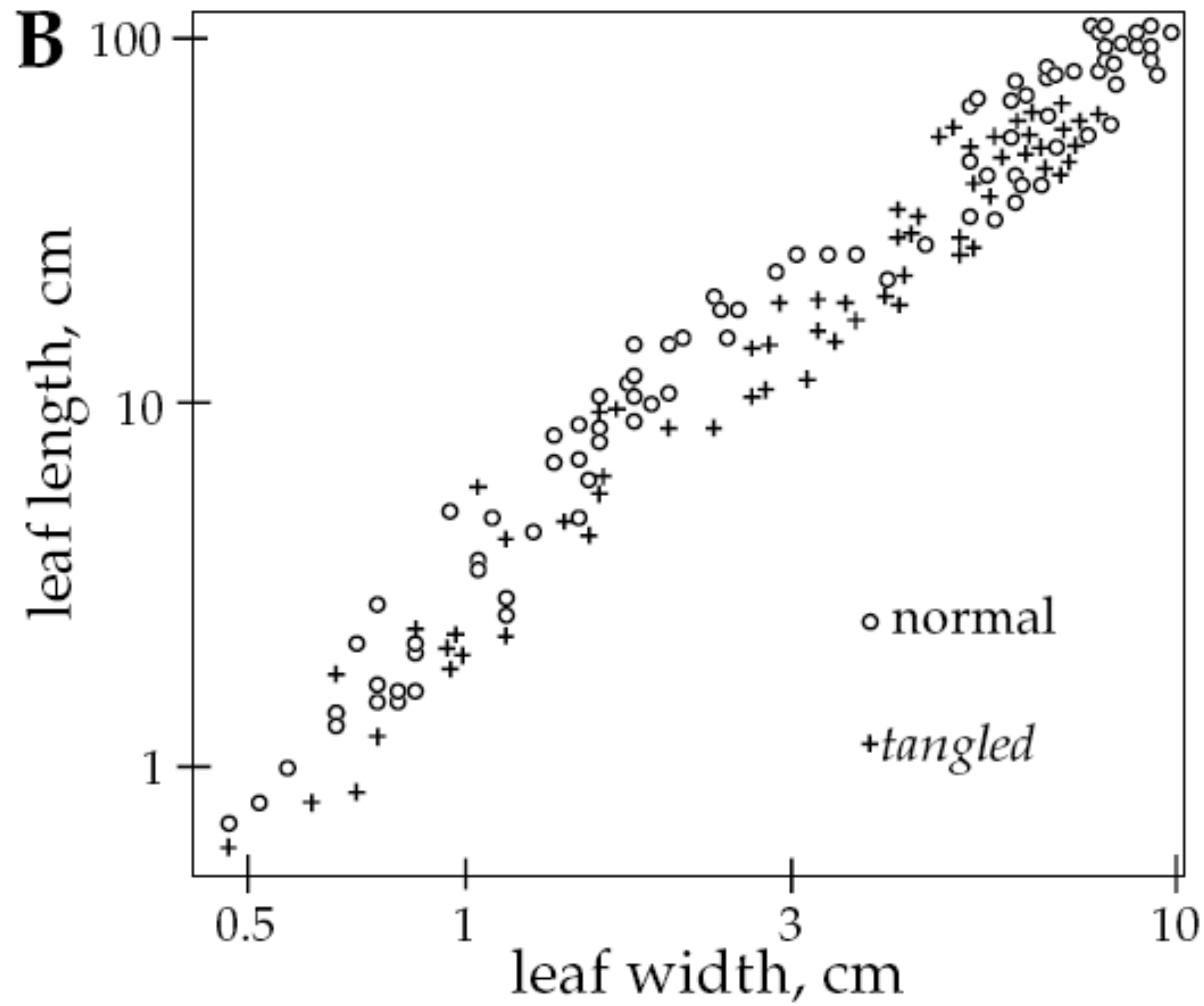


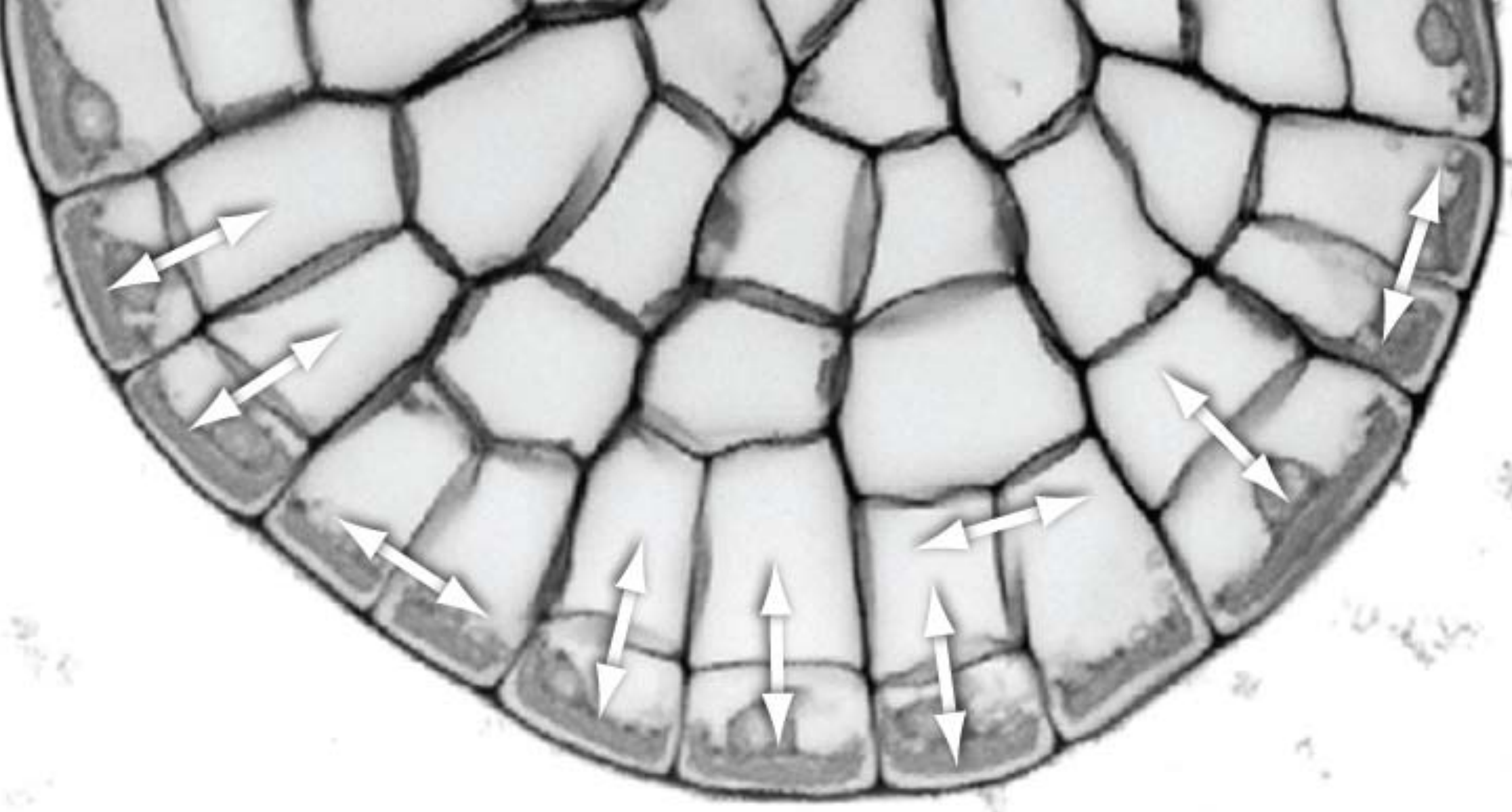
The tangled-1 mutation alters cell division orientations throughout maize leaf development without altering leaf shape

LG Smith, S Hake and AW Sylvester



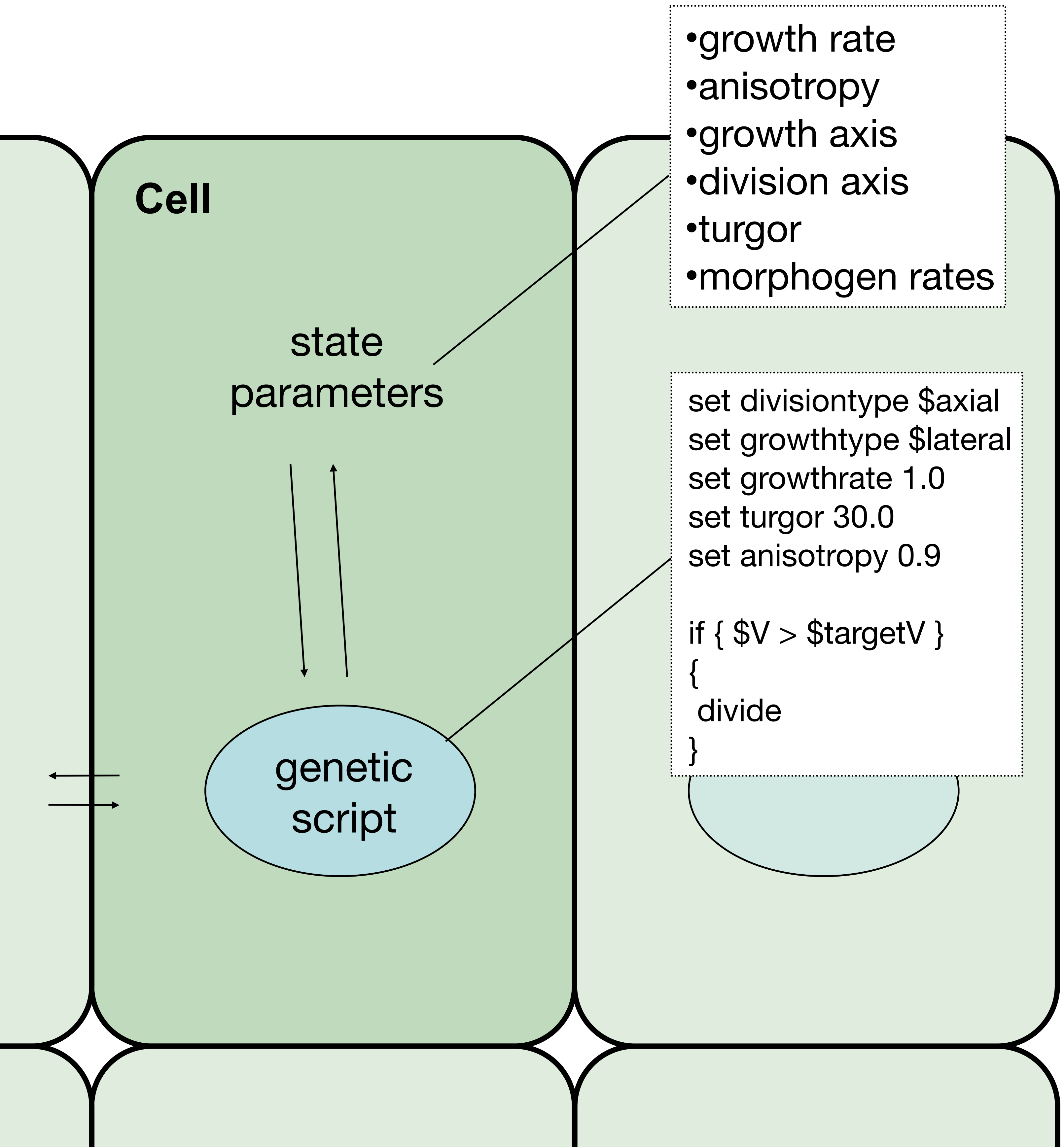

A
normal
1cm
5cm
50cm
50cm
tangled
1cm
5cm
50cm

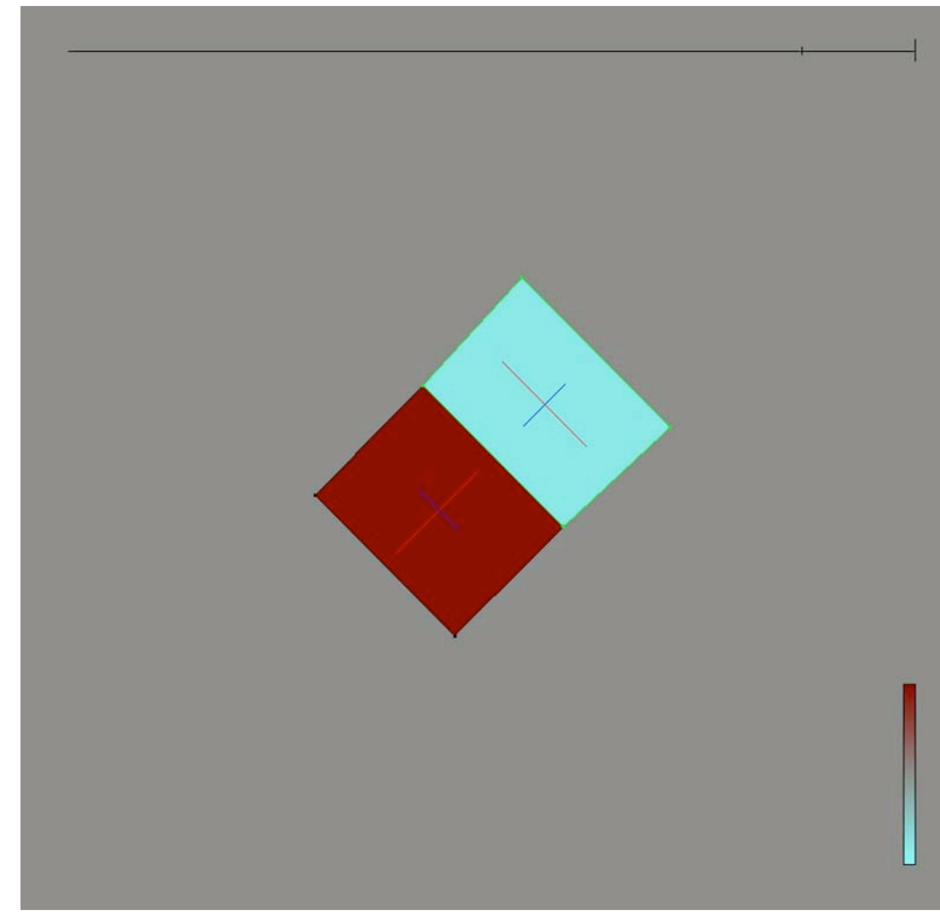

B
100
10
1
leaf length, cm
0.5
1
3
10
leaf width, cm
normal
tangled



How are the planes of cell division determined?

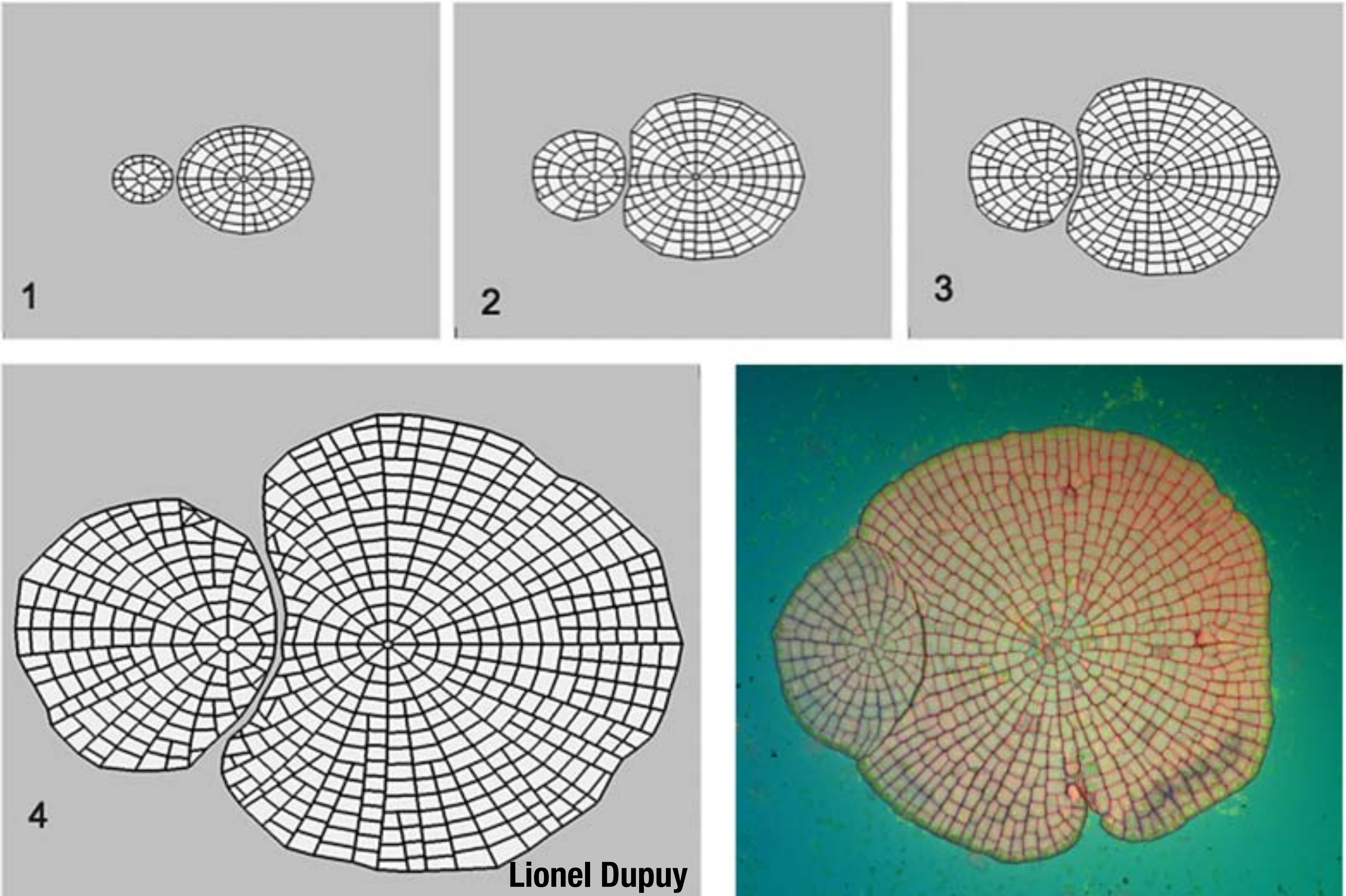
Cellular automata models for plant morphogenesis

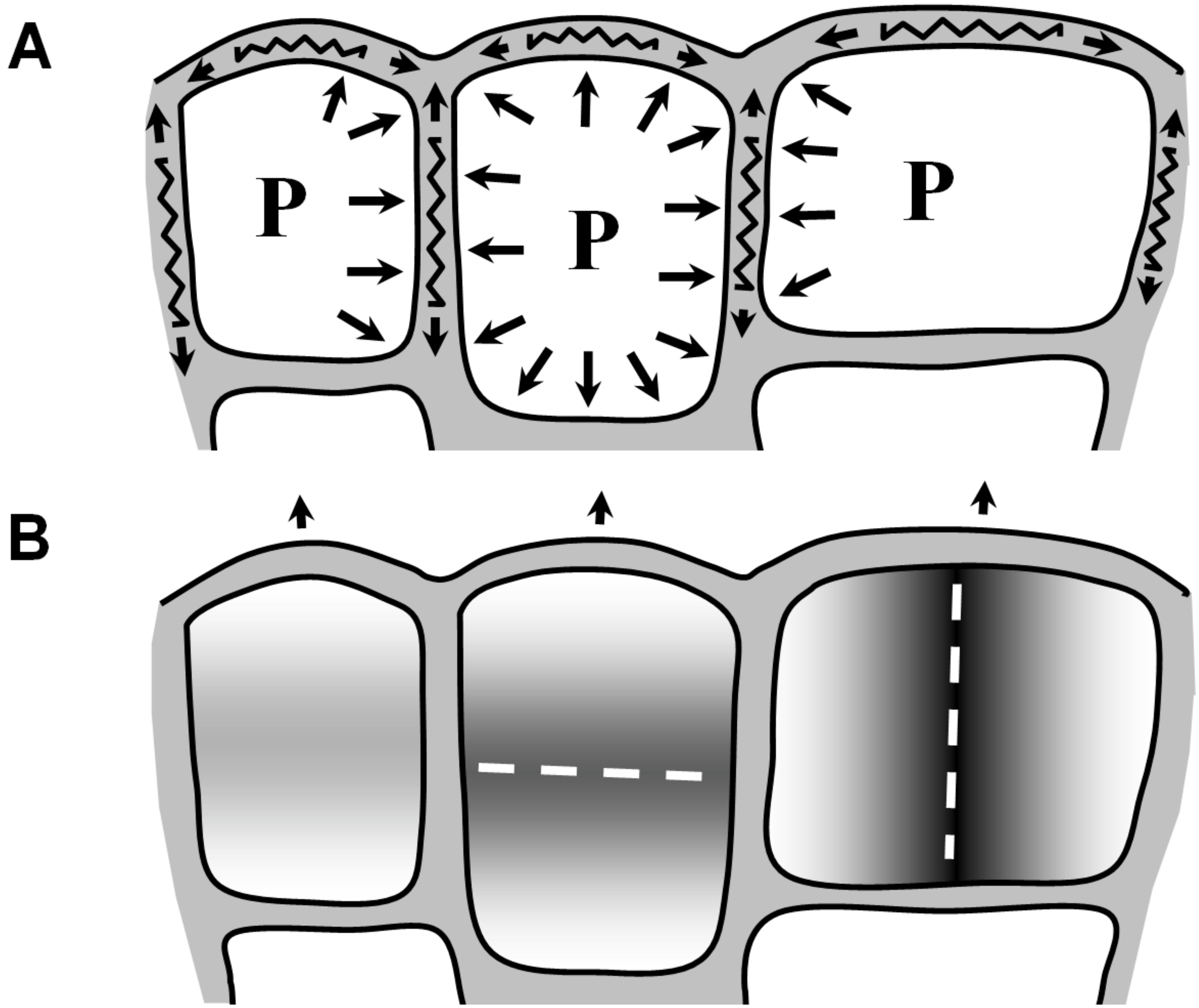




Tim Rudge

Contact between colonies





Model for the regulation of cell division:

(A) Cell activity influences cell and walls physical properties.
(B) Tissue growth constrains cell expansion and shape during development.
Cells then simply need a mechanism for sensing their own size and shape to allow the correct partitioning during division.

Marchantia polymorpha

New model system for developmental and Synthetic Biology studies:

- Thalloid liverwort
- Descendant of earliest land plants
- Gametophyte dominant phase of lifecycle
- Haploid genetics
- Vegetative propagation by gemmae
- Easily propagated *in vitro*
- Gametes induced by far-red light
- Crossing easy
- Spores stable for >1 year
- EST collection available
- Easily regenerates in tissue culture
- High frequency nuclear and plastid transformation
- Y chromosome and plastid genomes sequenced
- 280 MB genome sequence due in 2010

www.marchantia.org

Applications for Synthetic Biology

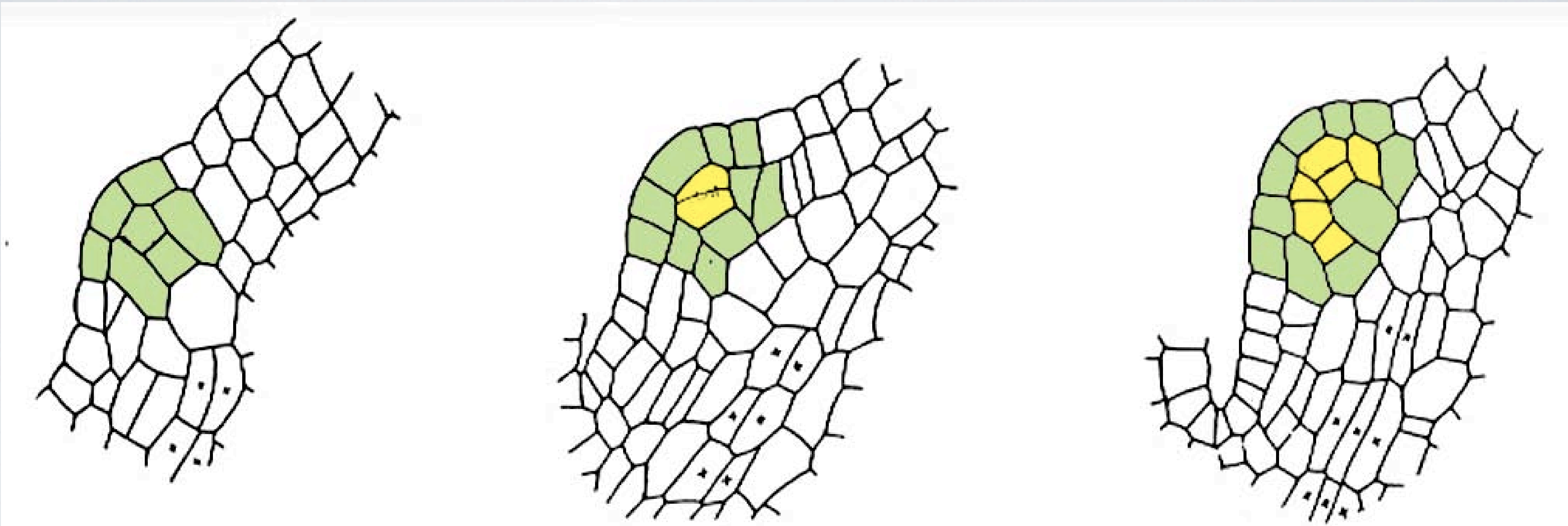
Cell autonomous genetic circuits with self-regulating properties

e.g. microbial engineering,
enviromental and biomedical sensors
engineering novel metabolic pathways

Morphogenetic circuits with self organising properties

e.g. microbial biofilms or self-organising communities for
bioremediation and bio catalysis
novel plant and algal feedstocks for bioproduction and bioenergy
tissue engineering

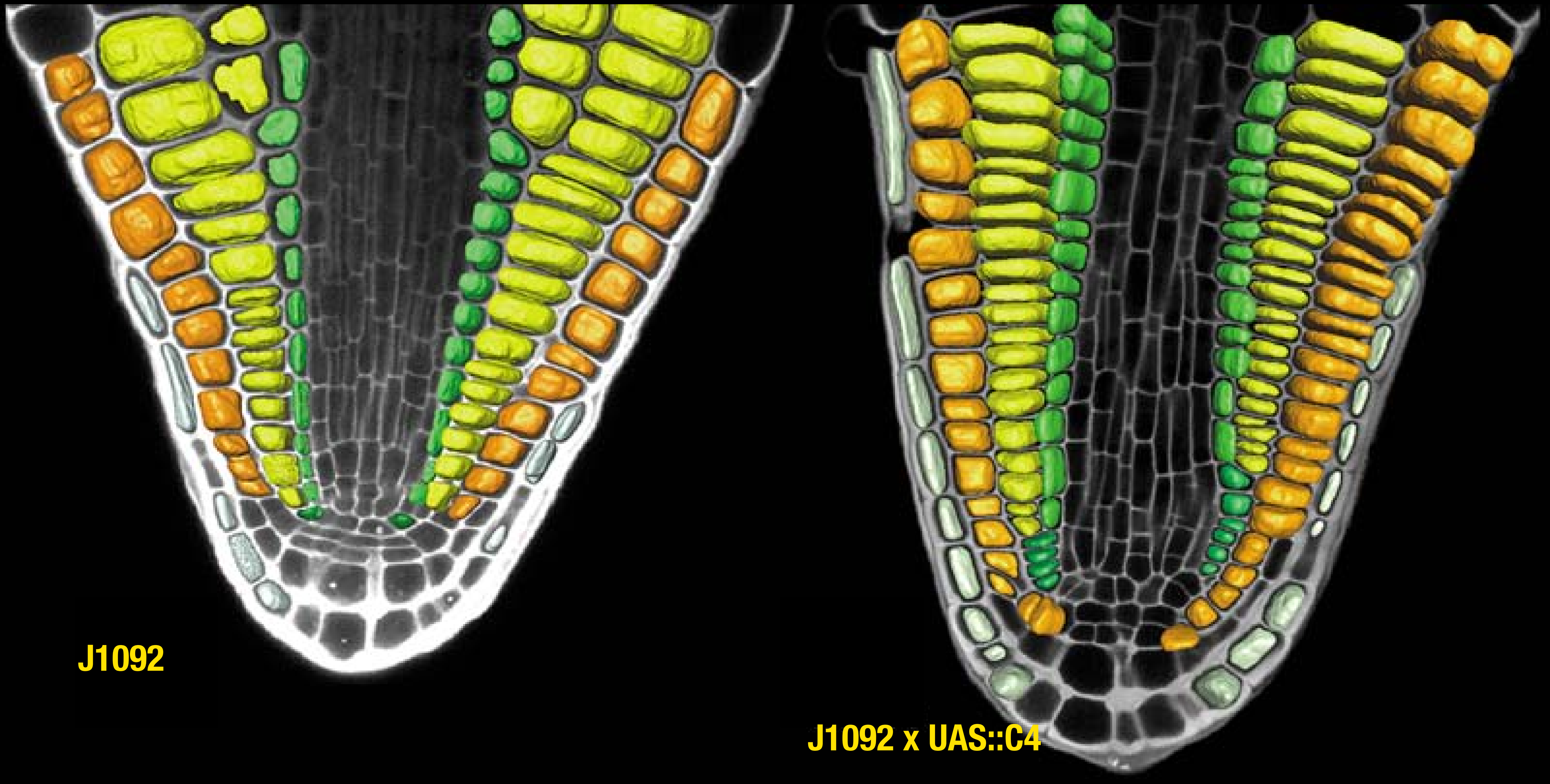
Engineering of neomorphic structures



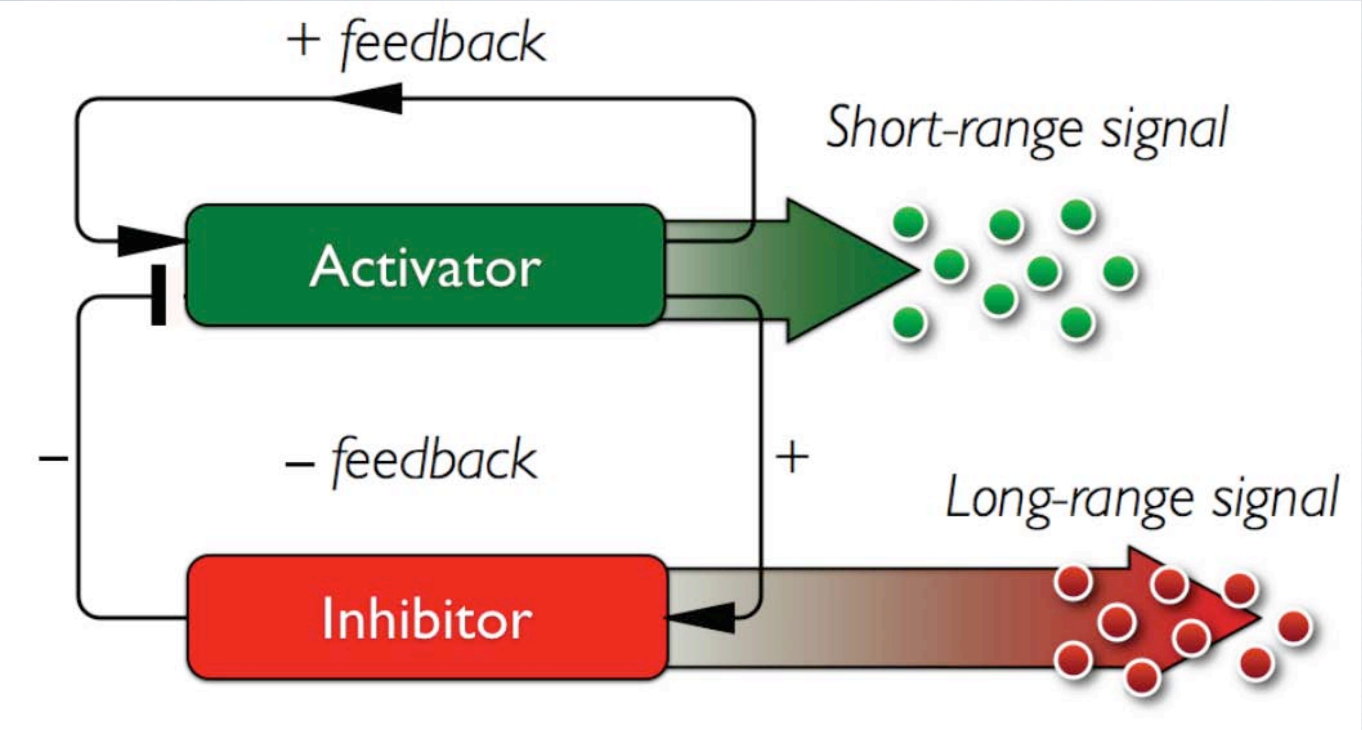
Trigger: initiate expression of a novel gene circuit during development

Patterning: define cohort of proliferating cells via intercellular signalling

Differentiation: confer new cell fates using endogenous regulators



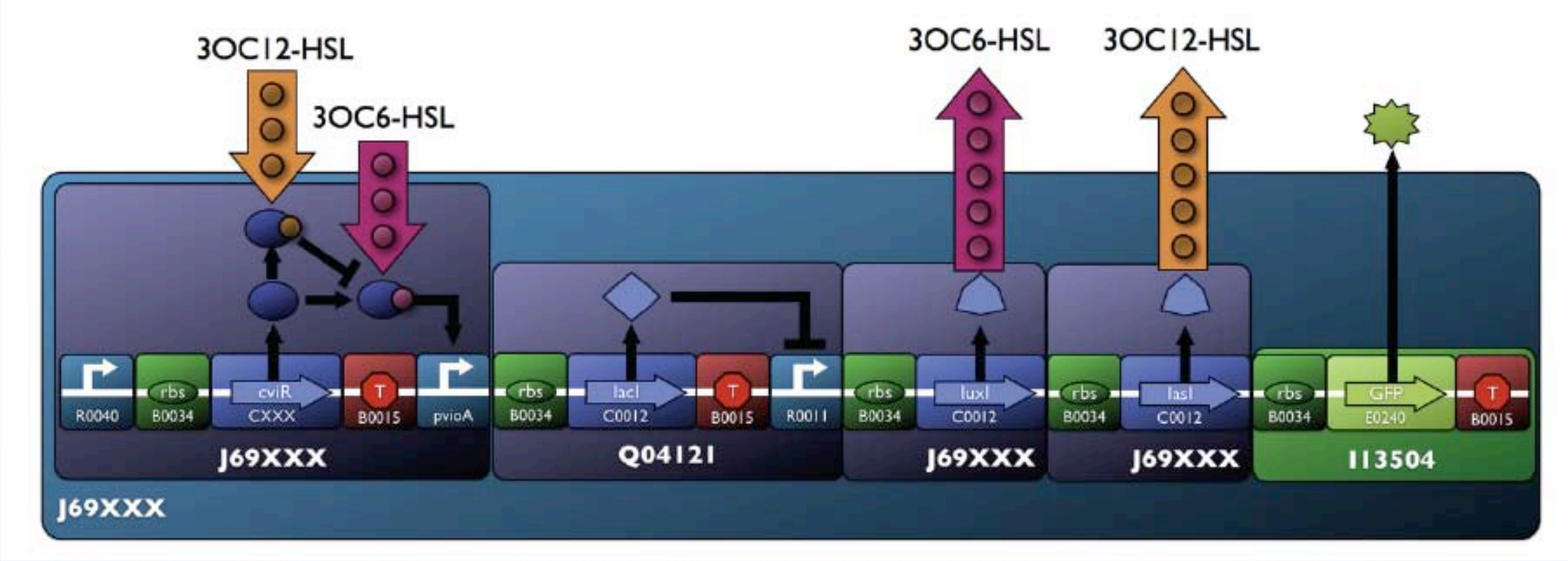
GAL4 targeted proliferation of the root cap during embryogenesis



Self-organising genetic circuits

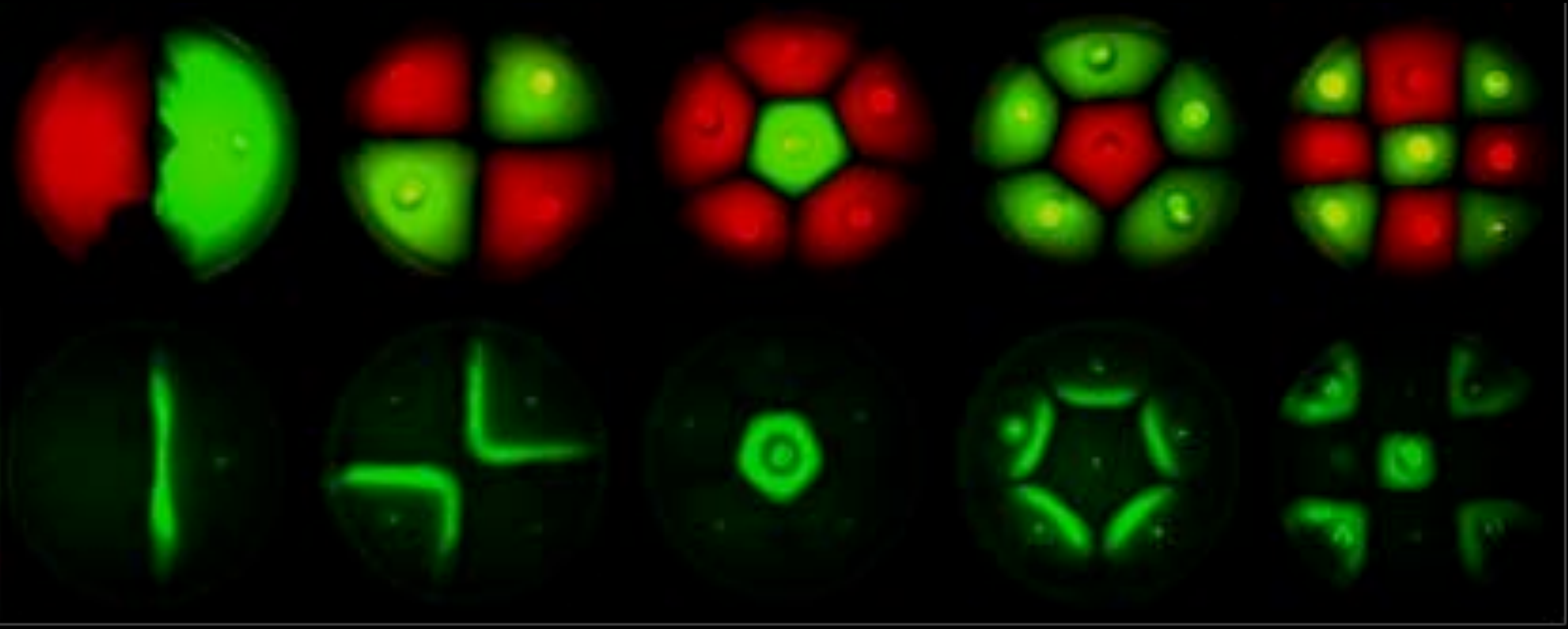
Use of microbial quorum sensing signals for cell-cell signalling and construction of Turing systems *in vivo*.

These can provide temporal-spatial switches for symmetry-breaking and to control fates of cell cohorts during development.



James Brown

Artificial intercellular signalling systems tested in microbes



http://www.plantsci.cam.ac.uk/Haseloff/iGEM2006/index.html

Benefits of rational morphogenetic design

Modern crop plants are derived from their natural ancestors by many generations of human selection and breeding. They differ mainly in the number and proportion of cells that contribute to different tissues of an organ.

Engineering of intercellular logic could provide simple and predictable tools for altering plant form